MARITIME FIRE SAFETY STANDARDS - SOME INSIGHT FROM AN AHJ

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ABSTRACT

The Coast Guard is the Authority Having Jurisdiction (AHJ) for the commercial marine industry in the United States. AHJ involvement begins with conceptual ship design and continues through the active service life of each commercial vessel. Recent advances in maritime regulation and fire safety standards, particularly for high speed craft, have presented some interesting issues which the Coast Guard as AHJ is learning to deal with. These include the importance of keeping the regulated industry informed of changes in policy and standards, interpretation of regulations, and the application of new fire safety standards for materials. The focus on material standards for high speed craft illustrates how modern fire test standards are being integrated into regulation and how advanced materials are being integrated into ship construction. These integrations have created a need for Coast Guard research in order to clarify regulatory requirements and to keep up with technology. Two current research projects dealing specifically with materials for use in high speed craft construction are described. The importance of industry involvement in every facet of marine safety is emphasized.

INTRODUCTION

Imagine as you and a few hundred people buckle into a high speed ferry boat and are whisked across the water at speeds you normally reach only on the freeway in your own automobile. A nervous thought runs through your mind and you consider this: "the 'powers that be' most certainly have ensured the safety of this vehicle?. . .they must have. . .." You find comfort in that supposition and lean back and enjoy the ride.

Very often in modern society, people place their trust in the "powers that be". With technology advancing at ever increasing rates, these "powers that be" are continually challenged to ensure safety. Most people in the fire safety industry will understand the "powers that be" to include the Authority Having Jurisdiction (AHJ). In the United States, the AHJ for high speed passenger vessels and all commercial shipping is the U.S. Coast Guard. The term "AHJ", while familiar to many in the fire safety industry, is surprisingly unfamiliar to many members of the Coast Guard.

The Coast Guard (or predecessor organizations) has been in the business of monitoring and regulating the commercial marine industry for almost two hundred years. Not until very recently has there been a major shift toward the incorporation of industry standards. Therefore, "AHJ" was an unnecessary term within the Coast Guard as the rules and enforcement came almost entirely from within the organization.

This recent trend of Coast Guard authority shifting toward industry standards is very applicable to the fire performance of materials. The origins of shipboard fire test standards are found in the 1920's and

1930's. Since that time the material standards have become an ever increasing cornerstone of the overall fire safety system aboard ships, particularly passenger ships.

PASSENGER VESSEL REGULATIONS AND FIRE TEST STANDARDS

One facet of modern society is the need to define absolutely everything in a legally binding sense. "Passenger ships" are defined in the Unites States by Title 46 of the U. S. Code. Regulations have been developed in the Code of Federal Regulations (CFR) also under Title 46, "Shipping, Chapter I, Coast Guard."[1] Internationally, the term "passenger ship" is defined by the International Convention for the Safety of Life at Sea (SOLAS)[2], a set of regulations drafted by the International Maritime Organization (IMO).

These regulations cover nearly every aspect of ship construction. The regulations are generally organized by vessel type. Lower limits are set to keep the regulations from affecting very small operators and pleasure craft. Other breakpoints have been written into the standards for steps in the level of safety depending on vessel type and size, number of passengers, route, etc.

While the focus here is on passenger vessels, particularly high speed craft (HSC), the basic philosophies of shipboard fire safety are applied by the Coast Guard to all types of vessels in lesser degrees. The basic principle since the 1950's has been "non-combustible" construction. Non-combustible is defined by fire tests and required for the majority of materials on ships. It is important to point out that the definition of "non-combustible" material, as used in marine regulation, is different than the way many designers consider the term as it relates to building construction. A non-combustible material "neither burns nor gives off flammable vapors in sufficient quantity for self-ignition when heated to approximately 750 °C," this being determined by a test procedure (ISO 1182) specified in the IMO's Fire Test Procedures Code (FTP Code).[3] With the ship's structure itself being non-combustible, that leaves only the outfitting, finishes, furnishings, supplies, and passenger's belongings which are able to burn. Many of the components in the ship's outfit and furnishing are also regulated in order to fulfill the basic principle of restricting the use of combustible material.

The High Speed Craft Code

There has been an escalation of requirements on passenger ships since the 1950's. Therefore, the IMO's High Speed Craft Code (HSC Code)[4] may be considered a milestone in the regulation of materials for ships. For the first time in many years there is a regulation that allows for the use of combustible materials in the structure of passenger ships. The application of the HSC Code is limited to passenger ships on voyages not further than 4 hours from place of refuge. It contains elements of a performance-based approach to safety, although it is certainly not a true performance based code. The HSC Code's philosophy is best described by taking a statement direct from the Preamble of the Code itself:

> *The safety philosophy of this Code is based on the management and reduction of risk as well as traditional philosophy of passive protection in the event of an accident. Management of risk through accommodation arrangement, active safety systems, restricted operation, quality management and human factors engineering should be considered in evaluating safety equivalent to current conventions. Application of mathematical analysis should be encouraged to assess risk and determine the validity of safety measures.*

With this safety philosophy, and through operational controls and route restrictions, the HSC Code has achieved what many believe to be an equivalent level of safety to the standard provisions of SOLAS.

In allowing combustible construction, the HSC Code defines a new class of material known as "fire-restricting material" with low flame spread properties, limited heat release rates, and limited smoke production. Specific material requirements for high speed craft can be found in Chapter 7 of the HSC Code.[4] The standards developed by the IMO for compliance with these material requirements are also significant for their incorporation of modern fire test methods.

Fire Test Standards

There are two significant recent developments in fire test standards for commercial ships: 1) the IMO's Fire Test Procedures Code[3], and 2) the IMO's "Standard for Qualifying Marine Materials for High Speed Craft as Fire-Restricting Materials", Resolution MSC.40(64)[5].

The FTP Code is significant in that it makes the use of the IMO fire test procedures mandatory for showing compliance with the SOLAS regulations (including the HSC Code). The FTP Code goes into effect in July 1998. The significance of this is that prior to this point, each Administration (government or other specified regulatory authority) enforcing SOLAS could use any fire test standard they wished. Many of them (the U.S. included) used their own domestic standards. Some of them use the IMO's "recommended" fire test procedures.

The IMO's standard for fire-restricting materials[5] is significant because it is the first marine fire test standard to specify the ISO 9705 [6] "room/corner test" and the ISO 5660 [7] cone calorimeter test methods, both of which are based on measuring heat release rate of construction products. This is significant because: 1) it specifies a full-scale fire test to evaluate the contribution to fire growth provide by the surface product in the shipboard compartments, 2) it is a departure from the traditional approach of requiring non-combustible structure, and 3) it incorporates two of the most modern of fire test methods at a time when many ship and building codes are still employing 30 and 40 year old flammability standards.

Table 1 lists the fire test standards required for some marine materials.

THE COAST GUARD AS AHJ

The Coast Guard carries out AHJ action in several different ways. These include writing regulations and policy directives (guidance), plan review, vessel inspection, port state control (for vessels of a foreign registry), and approval of equipment and materials. In many ways all of these measures are connected. Figure 1 depicts some of the interconnected steps in the shipboard material approval process.

The Coast Guard Marine Safety Center reviews plans of new ship construction and alterations for compliance with the regulations. In the field, Coast Guard marine inspectors board commercial vessels to check them against the approved plans. A vessel built to the HSC Code or any newer standard will receive closer attention from reviewers and inspectors. One aspect of plan review and inspection is to review for structural fire protection and materials. Many materials issues are not documented on plans and inspectors are left to determine suitability. The Coast Guard's type approval program does much to facilitate all parts of the plan review and inspection process.

Type approval of materials and equipment facilitates the industry by allowing a particular product (i.e. insulation, bulkhead panels, interior finish, deck coverings, etc.) to be fire tested once and approved for installation in an unlimited number of projects in the future. The fire tests must be performed at a Coast Guard accepted independent laboratory, with the results submitted to Coast Guard headquarters (Office of Design and Engineering Standards, Lifesaving and Fire Safety Standards Division) for type approval. The alternative to this process is to fire test a product for each installation. More information on the type approval process (and plan review and inspection) can be found in 46 CFR, specifically Subchapter Q[8] for approval of equipment and materials. In addition to the materials described in Subchapter Q, the Coast Guard is issuing type approvals for materials tested to the IMO fire test procedures.

AHJ ISSUES FOR DISCUSSION

This section will present some of the issues which the Coast Guard must deal with as AHJ. In most cases, the issues are probably similar to what the shore-side authorities must deal with in building construction. These are presented for purposes of information, discussion, and as an incentive for industry involvement in helping to clarify requirements or to help provide solutions.

AHJ Issue #1 - Keeping the industry informed

One of the challenges that the Coast Guard has as AHJ is ensuring that the industry is aware of the current standards. This is especially true in the function of material type approval. The regulatory amendment process takes several years, which leaves a heavy burden on policy guidance such as Navigation and Vessel Inspection Circulars (NVIC). One such document is "Guide to Structural Fire Protection", NVIC 9-97[9] (formerly known as "NVIC 6-80", but recently rewritten).

Policy guidelines also take time to revise, which means that the most current information may not always be readily available. The industry needs to be made aware of major shifts in policy such as the IMO's adoption of the mandatory FTP Code. So how does the industry find out such information? The industry itself is capable of getting this information by word of mouth and by direct contact with Coast Guard inspection offices, the Marine Safety Center, and Coast Guard Headquarters personnel (see list of contacts at the end of the paper). Other methods include the world wide web (visit http://www.uscg.mil/hq/msc/), various industry periodicals, and Coast Guard periodicals.

Manufacturers, shipbuilders, owners, marine surveyors, and others responsible for vessel construction and outfitting should contact the Coast Guard at the earliest opportunity in their particular project. This establishes a line of communication that is useful for clarifying issues as they come up, rather than in hindsight. In many cases, the "local Coast Guard" might be the Officer in Charge of Marine Inspection (OCMI) at the nearest port. The OCMI will have the answers to most questions, and will know where to refer in other cases. In some cases, such as type approval, Coast Guard offices at Headquarters must be involved. In all cases, however, the OCMI is a good place to start for the first time customer of the Coast Guard.

AHJ ISSUE #2 - Interpretation of regulation

Interpretation of a regulation or specification is a common problem in nearly every industry. It is helpful when the AHJ makes known the interpretations of vague requirements or clarification of how to comply with a difficult regulation. A recent example of this experience relates to the application of the HSC Code.

Although the IMO worked extensively on development of the HSC Code, there are still some areas open to interpretation of it's requirements, which poses a challenge to the Coast Guard as AHJ. Experience has shown that builders tend to use materials allowed in the past (in some cases by mistake, or perhaps allowed by other AHJ's) and tested to old standards. This is particularly the case with high speed craft designs which may have been built previously according to an older IMO Code: the Dynamically Supported Craft Code (DSC Code).[10]

The DSC Code has much looser provisions for structural fire protection than does the HSC Code. For example, where the HSC Code specifies a non-combustible or fire-restricting material, the DSC Code generally specifies a non-combustible material or other materials "provided that [the AHJ] is satisfied that the additional precautions taken are sufficient to ensure that an equivalent level of fire safety is achieved." This statement leaves a great deal of flexibility to the builder and huge openings for interpretations by the AHJ. One of the results of this is that when a "proven design" is now built to the HSC Code, it may require changes in design and construction in order to make it comply with the updated Code.

AHJ's should work together to make each interpretation similar, if not identical. The alternative is to cope with unique interpretations, essentially meaning application of regulation on a regional or topical basis. The IMO member administrations are working together to ensure unified interpretation of SOLAS regulations and the HSC Code. The Coast Guard is currently working to develop and publish guidance on applying the HSC Code in this country. Much of the work is in parallel with development at the IMO. The process is ongoing, and the more industry involvement that can be achieved, the better the result should be.

AHJ issue #3 - Applying "difficult" or expensive standards

In some cases an AHJ must enforce a standard that is expensive, difficult to comply with, or otherwise not suitable for everyone. The cause of this may be out of date standards, improper application, or simply the fact that the wrong standard was selected for incorporation into regulation or code. The question must be asked whether or not the standard is suitable to ensure safety.

A problem already identified with the IMO's test standard for qualifying fire-restricting materials[5] is that it is quite expensive for compartment lining materials. This is especially true if more than one formulation of a particular product or several different products are being developed for a specific application. This seems to have made manufacturers a bit hesitant to break into the relatively limited marine market. In the meantime, shipbuilders seem to generally favor the already proven non-combustible materials used in conventional ships. It can also be noted that, in general, many lightweight composite materials will not meet the strict standards set by IMO for use aboard HSC.

The solution to this and other such problems is complicated. Remember, regulations are not intended to save the owner money, they are usually intended to save lives by specifying a minimum safety standard. When a regulation is truly out of date or not applicable, the regulated industry should work with the AHJ to effect a change. On the other hand, if a regulation is suitable, the best course of action might be to let technology "catch up" or to develop equivalents that will still comply.

AHJ Issue #4 - Acceptance of alternative standards or equivalencies

Another problem that the Coast Guard must deal with in regard to material approval is whether or not to accept products tested to a standard other than those specified in CFR or SOLAS requirements. In

general, the Coast Guard does not accept products tested to "other" standards. To do so could potentially put an unfair burden on those who have chosen to comply with the applicable domestic or international standard; it would also open technical questions relating to test standard comparability or equivalency. This does not necessarily mean that the "other" standards are inadequate. In many cases these other standards are domestic standards in the country in which the product is manufactured. There are efforts underway to develop agreements with other marine regulatory authorities to accept each others type approvals, although these are generally not applicable to construction products at this point.

Most of the problems associated with application of various domestic standards are alleviated through efforts to harmonize, like the IMO did with the FTP Code. The FTP Code ensures an internationally accepted standard to comply with SOLAS, and eliminates the concerns that one domestic standard is not equivalent to another. This leaves only the problem with ensuring that the fire test procedures themselves are adequate to provide an acceptable level of safety onboard ships regulated by SOLAS. This is presently debatable, and the IMO does have plans in the future to take a closer look at their fire test procedures and to improve them as necessary. This cannot be done, however, without the research and data necessary to support any proposed changes.

The Coast Guard, the maritime industry, related industries, and fire labs should work together to develop this type of data if something is in need of a change. This can be accomplished via USCG R&D projects or industry-driven, industry-funded projects.

CURRENT RESEARCH

As discussed above, there are many choppy seas (and red tape) for vessels to cut through in reaching their destination of certification. This is especially true for vessels incorporating leading edge technology such as high speed craft. As an AHJ, recognizing a responsibility to promote safety and facilitate industry growth, the Coast Guard sponsors research in the area of fire and materials. Two current projects are concerned with clarifying requirements for construction materials in high speed craft.

Structural integrity of composite structures in fire

One project is intended to identify an alternative test method for ensuring adequate structural integrity of fiberglass (or other composite) bulkheads and decks in fire. The current standard is specified in IMO Resolution MSC.45(65), "Test Procedures for Fire-Resisting Divisions of High Speed Craft."[11] The standard specifies the IMO fire resistance test (Res. A.754(18))[12] for all divisions, with very slight modifications for load bearing and non-load bearing fire resisting divisions made of steel or aluminum. The difficulty arises when applying the standard to "other" load bearing fire-resisting divisions, meaning structures other than steel or aluminum.

In these cases, the specimen is mounted such that it is supported along only two opposite edges, a static load is applied, and deformation measurements are taken. Performance criteria include a limiting deflection or axial contraction and limiting rates of deflection or axial contraction (in addition to the performance criteria specified in the fire resistance standard Resolution A.754(18)). The concern with this method is the issue of adequate static loads, specified as 7.0 kN/m of the width for bulkheads and 3.5 kN/m^2 of the area for decks.

An earlier Coast Guard study completed a review of guidance for design loads in fiberglass structures.[13] The study found that, in practice, design loads for certain structures can reach over 7 times the static load specified in the test standard. It concluded that the most suitable method of establishing loads for fire endurance testing would be to test each specimen under the actual design load provided by the designer. In practice, this would most likely be a very difficult rule to apply, not only for the AHJ, but for the vessel owner who would have to fund all of this testing.

The Coast Guard continues its involvement in research to develop suitable design guidelines or test standards for fiberglass structures. One of the vehicles currently being used by the Coast Guard for this effort is the MARITECH program. MARITECH is a cost-shared R&D program jointly funded by the Defense Advanced Research Projects Agency (DARPA) and the marine industry.[14] One of the current MARITECH efforts includes a broad-scaled effort titled "Internationally Competitive Fast Ferries & Composite Ship Technologies." Composite materials will be characterized in terms of their temperature dependent properties. This information should be helpful in developing alternatives to the existing standard for fire-resisting divisions for high speed craft. It is not known yet if this will result in simple, inexpensive changes to the test method or if it will result in an entirely different regulatory approach to these fire-resisting divisions. Perhaps the most desirable result would be to have design guidance for structural fire protection of certain composite structures that would be focused on keeping the structure's temperature below a certain critical temperature either by design of the ship's systems or by insulation.

Flammability, heat release rate, and smoke production -

The second project addresses the flammability, potential contribution to fire growth in a compartment, and toxic smoke production of composite materials. Fire-restricting materials for bulkhead, wall and ceiling linings are qualified via the ISO 9705 room/corner test[6], as specified in the IMO's standard for qualifying fire-restricting materials (Res. MSC.40(64)).[5] Qualification (pass/fail) criteria for surface materials or linings are listed in Resolution MSC.40(64). They include a maximum heat release rate, smoke production rate, extent of flame spread, and criteria for no flaming drops or debris. The criteria specified by the IMO for this purpose are quite strict. A recent study by Mitusch[15] of the Norwegian Defence Research Establishment found that one particular material approved by the Federal Aviation Administration (FAA) failed the IMO requirements for heat release rate and smoke production when tested to the ISO 9705 standard.

Fire-restricting materials used for furniture and other components are qualified via the cone calorimeter, ISO 5660.[7] Unfortunately, Resolution MSC.40(64) does not specify qualification criteria for these components, and the decision is left to the AHJ as to what suitable criteria to use.

There are two primary goals with the current research: 1) to identify suitable qualification criteria from the cone calorimeter for fire-restricting materials used in furniture and other components or room contents, and 2) to identify suitable criteria for surface materials or linings when tested to ISO 5660, that would show consistency with the ISO 9705 results (i.e. it passes in one, it passes in the other). Goal number 1 is necessary to fill an immediate regulatory need. Goal number 2 is to eventually benefit industry by allowing the relatively inexpensive cone calorimeter test as an alternative to the sometimes prohibitively expensive ISO 9705 room/corner test. Even before goal number 2 is put into regulatory use, it may prove beneficial to industry by providing a powerful screening tool for new products with potential for passing the strict requirements specified by the IMO for the room/corner test. It will also be necessary to come to consensus agreement at IMO with regard to allowing ISO 5660 as an alternative test method for materials currently required to be tested to ISO 9705.

This project, currently in progress, includes small and large-scale testing in the cone calorimeter and ISO room. Predictive models will be employed to simulate room/corner test performance and the performance of furniture items or similar objects in the open and inside a room environment. The input for these predictive models is based on material data obtained from the cone calorimeter and other bench-scale tests. This project is of interest not only for the immediate regulatory need it will help fulfill, but because of its unique emphasis on composites and the correlation between bench-scale and full-scale tests. It is also an opportunity to validate certain types of predictive models.

CONCLUSION

This paper has provided a brief look into a few aspects of the Coast Guard's function as AHJ for passenger vessels, primarily high speed craft. Many recent developments in international maritime regulations and fire test standards have made the Coast Guard's job easier in some respects and more difficult in others. It is imperative that the marine, fire safety, and other related industries continue their involvement in the regulatory process. Improved vessel safety depends on this involvement. It is recognized that the issues presented in this paper are not unique to the marine industry, and the Coast Guard and other regulatory agencies are also encouraged to share relevant information. The discussions in this paper should help to smooth the seas for future cooperation between manufacturers, fire safety professionals, shipbuilders, and the Coast Guard.

REFERENCES

1. Code of Federal Regulations, Title 46 - Shipping, Chapter I - Coast Guard, Department of Transportation
2. International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended, International Maritime Organization, London, 1997.
3. International Code for Application of Fire Test Procedures (FTP Code), Resolution MSC.61(67), International Maritime Organization, London, 1996.
4. International Code of Safety for High Speed Craft (HSC Code), Resolution MSC.36(63), International Maritime Organization, London, 1995.
5. Standard for Qualifying Marine Materials for High Speed Craft as Fire-Restricting Materials, Resolution MSC.40(64), International Maritime Organization, London, 1994.
6. ISO 9705; "Fire Tests - Full Scale room test for surface products", International Organization for Standardization (ISO), 1991.
7. ISO 5660; "Fire Tests - Reaction to Fire - Rate of Heat Release from Building Products, International Organization for Standardization (ISO), 1991.
8. 46 CFR Parts 159 - 164; Subchapter Q - Equipment, Construction, and Materials: Specifications and Approval.
9. USCG, Guide to Structural Fire Protection, Navigation and Vessel Inspection Circular No. 9-97, Commandant (G-MSE-4), U.S. Coast Guard, Washington, DC, 31 Oct 1997.
10. Code of Safety for Dynamically Supported Craft, Resolution A.373(X), International Maritime Organization, London, 1977.
11. Test Procedures for Fire-Resisting Divisions of High Speed Craft, Resolution MSC.45(65), International Maritime Organization, London, 1995.
12. Recommendation on Fire Resistance Tests for "A", "B" and "F" Class Divisions, Resolution A.754(18), International Maritime Organization, 1993.
13. Wolverton, C. D., "Design Loads for Fiberglass Bulkhead and Deck Structures", Report No. CG-D-44-95, U.S. Coast Guard Research and Development Center, Groton, CT, December 1995.

14. Blenkey, N., ed., "More Projects picked for MARITECH", *Marine Log*, 100(6), pp. 66-67, June 1995.
15. P. D. Mitusch, "Short Communication: Aircraft Interior Panels Tested According to the Maritime High-Speed Craft Code", *Fire and Materials*, Vol. 21, pp. 187-189, John Wiley & Sons, 1997.

LIST OF CONTACTS WITHIN THE COAST GUARD

For information on maritime regulations, fire protection, material and equipment approvals, contact:

Commandant (G-MSE-4)
Lifesaving and Fire Safety Standards Division,
Office of Design and Engineering Standards
2100 Second St., S.W.
Washington, DC 20593
Phone: (202)267-1444
Fax: (202)267-1069

For information on plan review and vessel inspection, contact:

Commanding Officer
U.S. Coast Guard Marine Safety Center
400 7th Street, S.W.
Washington, DC 20590
Phone: (202)366-6481
Fax: (202)366-3877

For general information on maritime issues, contact:

National Maritime Center
U.S. Coast Guard
4200 Wilson Blvd, Suite 510
Arlington, VA 22203-1804
Phone: (703)235-0018
Fax: (703)235-1602

For your local Coast Guard offices, use the phone book to locate the nearest Marine Safety Office or District Command.

On the World Wide Web, you can find helpful marine safety information, as well as links to the Code of Federal Regulations and other technical information at http://www.uscg.mil/hq/msc/

TABLE 1 - FIRE SAFETY REQUIREMENTS FOR SOME MARINE PRODUCTS

MATERIAL OR PRODUCT	APPLICABLE TEST METHODS
Domestic Requirements -	
Deck Coverings	46 CFR 164.006
Structural Insulations	46 CFR 164.007 46 CFR 164.009 ASTM E-119
Bulkhead Panels	46 CFR 164.008 46 CFR 164.009 ASTM E-119
Noncombustible materials	46 CFR 164.009
Interior Finishes	46 CFR 164.012 ASTM E-84
SOLAS requirements -	
Non-combustible material	FTP Code Part 1 ISO 1182
Fire resisting divisions	FTP Code Part 3 IMO Res. A.754(18) ISO 834
Surface materials and finishes, including Primary deck coverings	FTP Code Part 5 (surface flammability) IMO Res. A.653(16) FTP Code Part 2 (smoke/toxicity) ISO 5659: Part 2 FTP Code Part 6 (for primary deck coverings only)
Vertically supported textiles and films	FTP Code Part 7 IMO Res. A.471(XII) (as amended by Res. A.563(14))
Upholstered Furniture	FTP Code Part 8 IMO Res. A.652(16)
Bedding Components	FTP Code Part 9 IMO Res. A.688(17)
Fire resisting divisions for High Speed Craft	IMO Res. MSC.45(65) and Res. A.754(18)
Fire-restricting materials for High Speed Craft	IMO Res. MSC.40(64) ISO 9705 ISO 5660
The contents of this table do not necessarily reflect all regulatory requirements for a particular marine product. Note that it is extremely important that the appropriate regulations be read in conjunction with the applicable test method listed in order to apply the proper test method and classification to each potential product use.	